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MEASUREMENT OF THE ATTENUATION OF EXPERIMENTAL EARMUFFS FOR THE--ETC(U)
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ROYAL AIRCRAFT ESTABLISHMENT

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ROYAL AIRCRAFT ESTABLISHMENT

Technical Memorandum FS 371

Received for printing 30 December 1980

MEASUREMENT OF THE ATTENUATION OF EXPERIMENTAL EARMUFFS FOR THE MK 4 FLIGHT HELMET

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SUMMARY

Acoustic attenuation measurements have been made on three pairs of earmuffs including samples of alternatives to the B2 production shells used on the Mk 4 flight helmet, using both the objective and semi-objective methods of test. In addition, an example of the B2 production earmuffs was also tested.

The differences between the results are discussed with reference to the relative merits of the earmuffs and the reliability of the test methods.

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1 INTRODUCTION

A continuing interest of the Human Engineering Division is in the improvement of methods of reducing noise levels at the ears of aircrew since high noise levels reduce speech intelligibility, mask warning signals and audio cues and generally degrade aircrew performance.

This Memorandum describes the results of objective and semi-objective acoustic attenuation measurements made on alternative forms of earmuff assembly intended for the Mk 4 flight helmet which have recently become available for comparison with current earmuffs, an example of which was also included.

The method of measuring the attenuation provided by earmuffs has been discussed in detail in Ref 1, and a previous Memorandum[2] describes similar tests performed on other experimental earmuffs, which were also intended as alternatives to the current Mk 4 flight helmet earmuffs.

Differences between the data are discussed and conclusions drawn concerning the relative merits of the various earmuffs.

2 EQUIPMENT AND EXPERIMENTAL METHOD

The apparatus and methods used were very similar to those used in previous tests and described in detail in Ref 2. Therefore, only a brief summary will be given here, except where there were substantial differences in either apparatus or method.

2.1 Noise generation and fields

The noise fields used during this work were generated using the arrangement and equipment shown in Fig 1. The positioning of the loudspeakers in the semi-reverberant room was such as to produce the necessary diffusity of the noise field within a cube of 30cm side at the centre of the room.

As in previous tests[2], pink noise was used for the objective tests whilst the field was raised at high frequencies for the semi-objective tests in order for the analysis equipment to cope with the wide dynamic range of occluded spectra.

Care was taken to assure the protection of the hearing of subjects. The A-weighted level of the sound field was 97 dB(A) lasting for approximately 15 minutes. Calculation shows this to be approximately equivalent to 82 dB(A) for 8 hours, well within the maximum recommended industrial noise dose of 90 dB(A) for 8 hours over a working lifetime[3].

2.2 Noise measurement and analysis equipment

Measurements of the noise fields during the objective tests were made using the Bruel and Kjaer Type 4153 Artificial Ear mounted in a heavy metal casing and placed upon a vibration isolation structure in the semi-reverberant room so that the microphone cartridge of the Artificial Ear was located at the centre of the 30cm cube mentioned in section 2.1. A full description is given in Ref 2.

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During the semi-objective tests, measurements of the noise field reaching the subjects' ears were made using Knowles Type BT 1759 electret microphones. One microphone was fitted to each ear at the entrance to the ear canal and a flat lead, to minimise earshell leakage, fed the signal to the analysis equipment.

Analysis of all signals was performed using a Bruel and Kjaer Type 2131 Digital Frequency Analyser, remotely controlled by a Hewlett-Packard Type 9825A desktop computer.

2.3 The earmuffs

The following three pairs of earmuffs were used in the tests:

Type A - polyester glass compound shells, with flanges
Type B - dough moulded compound, without flanges
Type C - B2 production shells (Mk 4 helmet).

All types were fitted with foam-filled seals and incorporated telephones. These seals have two small holes in the skin, located at each end of the major axis and facing the flanges of the earshells to allow air to escape from or enter the seals during changes of altitude or seal compression. However, it has been found that when the earmuffs are placed on the Artificial Ear, the holes are occluded which prevents venting of the seal. In previous tests[2] earmuffs had to be tested 10 minutes after fitting to the Artificial Ear in order for changes of seal geometry to stabilise and have minimal influence on low frequency earmuff attenuation. However, when two holes were made in the outer skin of the material containing the foam, at either end of the major axis, attenuation measurements could be made immediately without any noticeable effect on the attenuation spectra.

Accordingly, all earmuffs tested here had two small holes made in the outer skin of the foam-filled seals at either end of the major axis, so that attenuation measurements could be made immediately after fitting the earmuffs to the Artificial Ear.

For the objective tests, each earmuff in turn was positioned centrally upon the mounting plate of the Artificial Ear and a 1kgf spring load applied[1]. For the semi-objective tests, pairs of earmuffs were mounted in an auxiliary headband in the same manner as described in Ref 2. In this reference it was suggested that an investigation into the method of mounting the earmuffs in the headband should be undertaken to provide a reliable method of assessing helmet earmuffs without the wearing of flight helmets. Subsequent experiments provided this information and an account of this investigation will be found in the Appendix. The results demonstrated the validity of measurements of earmuff attenuation made using the auxiliary headband.

2.4 Subjects

Seventeen subjects were used for the semi-objective tests, although the precise numbers tested with each pair of earmuffs varied. Seventeen were tested with types A and B, while 12 were tested with type C. All were drawn from operational aircrew at RAF Honnington and had short haircuts and were clean-shaven.

2.5 Procedure

In all cases, the attenuation was calculated by the insertion loss technique, this being the difference in dB between the unoccluded and occluded spectra.

2.5.1 Isolation of the Artificial Ear

Before any attenuation measurements of earmuffs could be made using the Artificial Ear, it was necessary to know that the acoustic isolation of the device was sufficient to ensure that the attenuation spectra measured were not contaminated due to leakage of noise through the device. Accordingly, all potential sources of leakage in the device were sealed and isolation was measured by occluding the microphone cartridge of the Artificial Ear with a thick-walled brass cup, shown in section in Fig 2.

The Artificial Ear was placed upon the structure described in section 2.2 and the noise field given in section 2.1 was used. Four unoccluded spectra, each determined using a linear averaging time of 8 seconds, were measured and the average computed. The brass cup was then placed centrally over the microphone cartridge and 'ringed' into position with a thin layer of silicon grease. Grease was simpler to use than the thin layer of plasticine used previously[2]. An identical noise field was generated and the average of four, 8 second, occluded spectra was computed.

2.5.2 Objective tests

The noise field described in section 2.1 was generated and the average of four, 8 second, unoccluded spectra computed. The first earmuff to be tested was then fitted to the Artificial Ear and a 1kgf spring load applied. The identical noise field was generated and the occluded spectrum calculated. This procedure was repeated for each earmuff in turn and each earmuff was tested five times.

2.5.3 Semi-objective tests

Each subject was fitted with a Knowles Type BT 1759 electret microphone at each ear, seated with his head at the centre of the noise room, exposed to the noise field described in section 2.1 and the unoccluded spectrum at each ear measured.

The first pair of earmuffs to be tested were then fitted to the subject, care being taken to ensure a good fit and that the flat microphone lead produced minimal leakage. The noise field was regenerated and the subject adjusted the fit of the earmuffs so that the noise reaching his ears was a minimum (as previously instructed) and when the subject was satisfied with the fit of the earmuffs, the occluded spectrum at each ear was measured. This procedure was repeated for all three pairs of earmuffs in turn. On a final test run, the unoccluded spectrum at each ear was re-measured for purposes of ensuring that the noise field had not changed during the course of the experiment. In all cases, the noise field remained constant with time. Accordingly, the mean of the two unoccluded spectra for each subject was used in calculations of earmuff attenuation.

3 RESULTS

3.1 Isolation of the Artificial Ear

Fig 3 shows the 1/3 octave band isolation of the Artificial Ear. In all 1/3 octave bands, the isolation sufficiently exceeds (10 dB) expected values of objectively measured attenuation. On this basis, a series of objective measurements were performed, the results of which are described in section 3.2.

3.2 Objective tests

The mean attenuation curves obtained from five measurements on each earmuff are shown in Figs 4 to 6 together with the associated standard deviations. Fig 7 shows the mean and standard deviation for each type of earmuff and Fig 8 shows a comparison between the data obtained here for the type C earmuffs with those obtained approximately 7 months previously for the same pair of earmuffs and reported in Ref 2. The following points may be observed from the figures:

(i) For the type C earmuffs, there is generally good agreement between the data obtained in this experiment and those obtained previously, although a 2-tailed Students t-test revealed significant differences at four frequencies (800, 2500, 3150 and 6300 Hz) at the 1% level of significance.

(ii) For all types, the attenuation of the two muffs of each pair are in good agreement.

(iii) All earmuffs exhibit a resonance in the region of 250-400 Hz, although the effect is most pronounced for the type C earmuffs.

(iv) Earmuffs types A and C exhibit approximately 5 dB more attenuation than type B at frequencies up to 250 Hz. From 315-400 Hz, type A is some 5dB higher than type B which in turn is 5-10 dB higher than type C. Above 1000 Hz the situation becomes confused, although the three levels are within 5-6 dB of each other except in the 1.25 to 1.6kHz bands where the differences are spread over 10 dB.

The two main findings of the objective tests are that the type B earmuffs have some 5dB less attenuation at low frequencies (up to 250 Hz) than either of the other types of muff and that while all types exhibit a resonance in the region of 250-400 Hz, the effect is most pronounced for the type C muffs. As has been suggested previously[2], this resonance probably arises from an interaction between the stiffness constants of the enclosed volume of air inside the earmuffs and the stiffness constants of the cushion.

3.3 Semi-objective tests

The mean attenuation curves for each earmuff together with standard deviations are shown in Figs 9 to 11. Fig 12 shows the comparison between each earmuff type and Fig 13 compares the data obtained here for the type C earmuffs (12 subjects) with those obtained previous (15 subjects)[2] for the same pair of earmuffs. The following points may be observed from the figures:

(i) For the type C earmuffs, there is close agreement between the data obtained here and those obtained previously. A 2-tailed Students t-test failed to reveal any significant differences between the two sets of data at any test frequency, at the 1% level of significance.

(ii) There is close agreement between the attenuation spectra obtained for the two muffs of each pair for all types.

(iii) At all frequencies up to 3150 Hz, the type A earmuffs show significantly greater values of attenuation than either of the other types. A 2-tailed Students t-test showed these differences to be significant at the 1% level. Up to 500 Hz, the attenuation of types B and C are in close agreement. In the 800-3150Hz frequency band, type C's attenuation is some 7-8 dB lower than that of type B's which in turn is 7-8 dB lower than that of type A. These differences are statistically significant at the 1% level.

(iv) These curves are quite different from those obtained in the objective tests, across the entire frequency range.

4 DISCUSSION

The results of both the objective and semi-objective tests demonstrated good agreement between the attenuation spectra for earmuffs type C measured in this experiment with those obtained approximately 7 months previously for the same pair of earmuffs. Although statistical tests revealed significant differences between the objective test results at four frequencies, these data support earlier assumptions regarding the reliability of the two test methods.

The objective tests revealed that all the earmuffs tested exhibited a resonance in the region of 250-400 Hz, although the effect was most marked for the type C earmuffs. Previous tests have shown that these resonances disappear when the foam-filled seals are replaced with a thin layer of plasticine, without lowering the attenuation, which indicates, as theory predicts, the importance of a good match between seal and earshell to provide a resonance-free earmuff.

The semi-objective tests indicated an overall lowering of attenuation relative to the objective test findings, and no obvious evidence of the resonance. Over the majority of the frequency range, the attenuation of the type A earmuffs was significantly greater than that of the other types.

5 CONCLUSIONS

The first clear result obtained in this experiment is that, as previously shown, the objective test method generated data that are substantially different from those data obtained using the semi-objective test method. However, semi-objective data correlate well with data obtained using the standardised Real Ear at Threshold method[4], except in the lower frequency bands, and may be viewed as providing a valid measure of attenuation[5]. Additionally, the data obtained both here and previously for the type C

earmuffs support earlier assumptions regarding the repeatability and reliability of both the objective and semi-objective test methods.

The semi-objective tests indicated that the performance of the type A earmuffs was superior to that of the other types at low and mid frequencies.

Appendix

TEST OF AN EXPERIMENTAL HEADBAND FOR USE IN THE MEASUREMENT OF THE ATTENUATION OF FLIGHT HELMET EARMUFFS

A.1 Introduction

Recently, improved earmuff assemblies intended for flight helmets have become available for comparison with current types of earmuffs. In subjective or semi-objective testing, considerable time is required to fit the earmuffs to the helmet and the helmet to the subjects. A need has therefore arisen, due to the large number of earmuffs requiring to be tested, for a series of rapid, comparative attenuation measurements.

Accordingly, an experimental headband system with a modified earshell support system has been constructed at RAE which enables earmuffs to be held in place on subjects' heads without the helmet having to be worn.

As stated in section 2.3, there is some doubt as to whether attenuation measurements made using this headband produce data that agree with those which would be obtained using the same headband but with a different earshell support system. As a first step, an assessment of the validity of data measured using the experimental headband was made for a pair of commercially available hearing protector earmuffs which are supplied with their own headband. The attenuation provided by these earmuffs was measured when they were mounted both in the experimental headband and their own headband.

A.2 Equipment and method of test

The noise field, equipment and semi-objective method of test used were identical to those used for the main experiment and described in sections 2.1, 2.2 and 2.5.

One pair of commercially available hearing protector earmuffs (Amplivox Sonogard) was used together with its associated headband. For each test the earmuffs were mounted either in this headband or in the experimental headband. The latter device is described in detail in Ref 2.

Fifteen subjects were used in this experiment, 12 males and three females, drawn from the research staff of RAE. The thickness and length of hair varied from one subject to another.

Measurements of the attenuation provided by the earmuffs were made when they were mounted both on their own headband and on the experimental headband.

A.3 Results and discussion

The mean attenuation spectra obtained from the 15 subjects for each earmuff on the standard headband are shown in Fig A1 together with the standard deviations. Fig A2 shows the corresponding results for the experimental headband. It can be seen that there is very close agreement between the results obtained for the left and right earmuffs using either headband. Fig A3 shows a comparison between the mean attenuation spectra obtained using the two headbands. Two-tailed Students t-tests performed on these data failed to reveal any significant differences between the mean attenuation spectra at the

1% level of significance. It should however be noted that over the majority of the frequency range the experimental headband produced approximately 2-3dB more attenuation than the standard headband.

In all cases the standard deviations were somewhat greater than those obtained in earlier work on Mk 4 helmet earmuffs[2], but were similar to the standard deviations found in similar tests on the same type of hearing protectors[1].

A.4 Conclusions

The attenuation spectra of a pair of commercially available hearing protector earmuffs have been measured by semi-objective methods using 15 subjects. The earmuffs were mounted on their standard headband and also on the experimental headband. The results showed no statistically significant differences between the measured attenuation spectra.

It may therefore be concluded that measurements of earmuff attenuation made using the experimental headband produce data that are comparable with those which would be obtained if the headband designed for the earmuffs were used. For purposes of comparing flight helmet earmuffs, the experimental headband appears to produce valid experimental data.

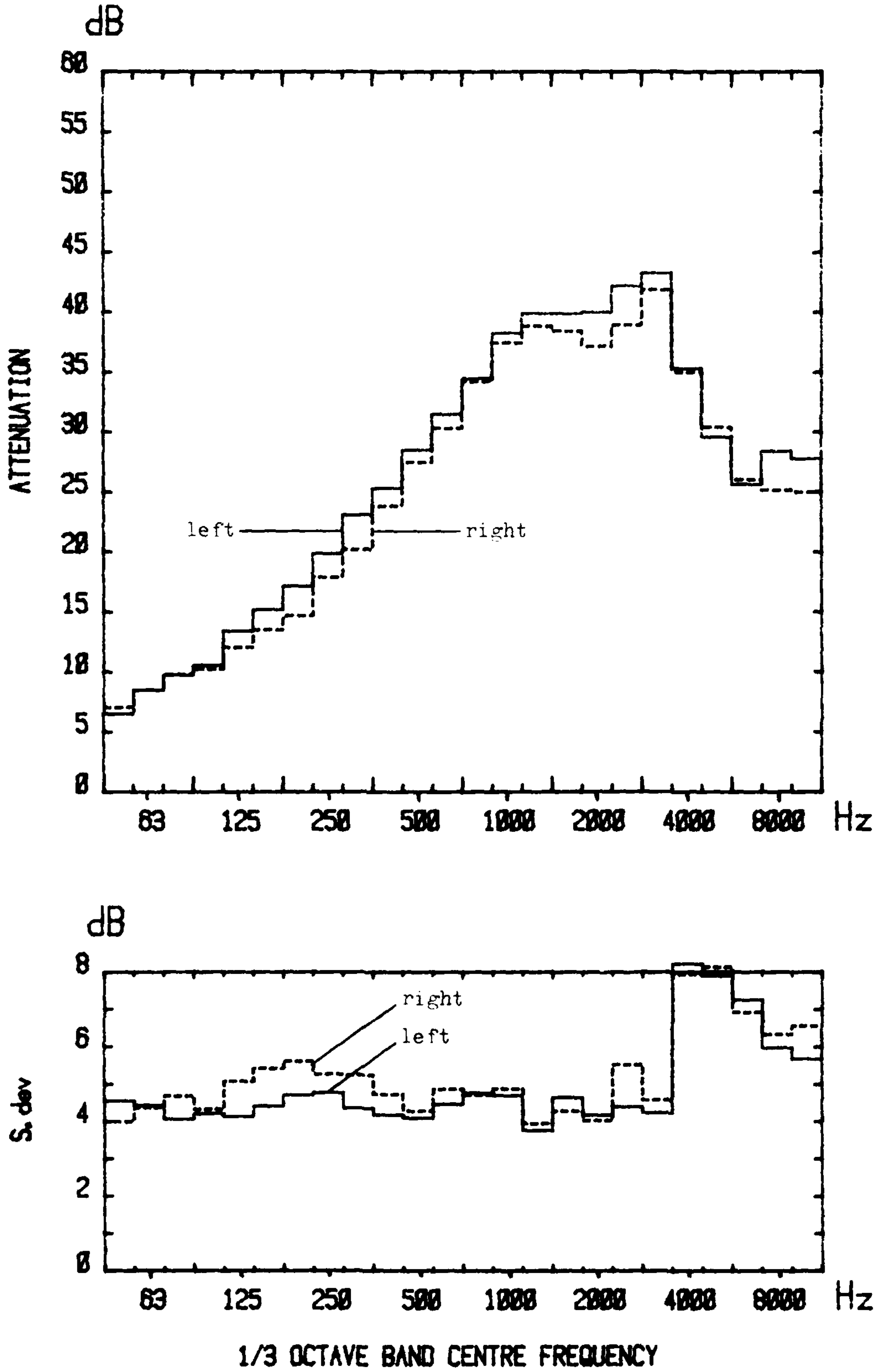

Fig A1 Mean attenuation spectra of earmuffs on standard headband

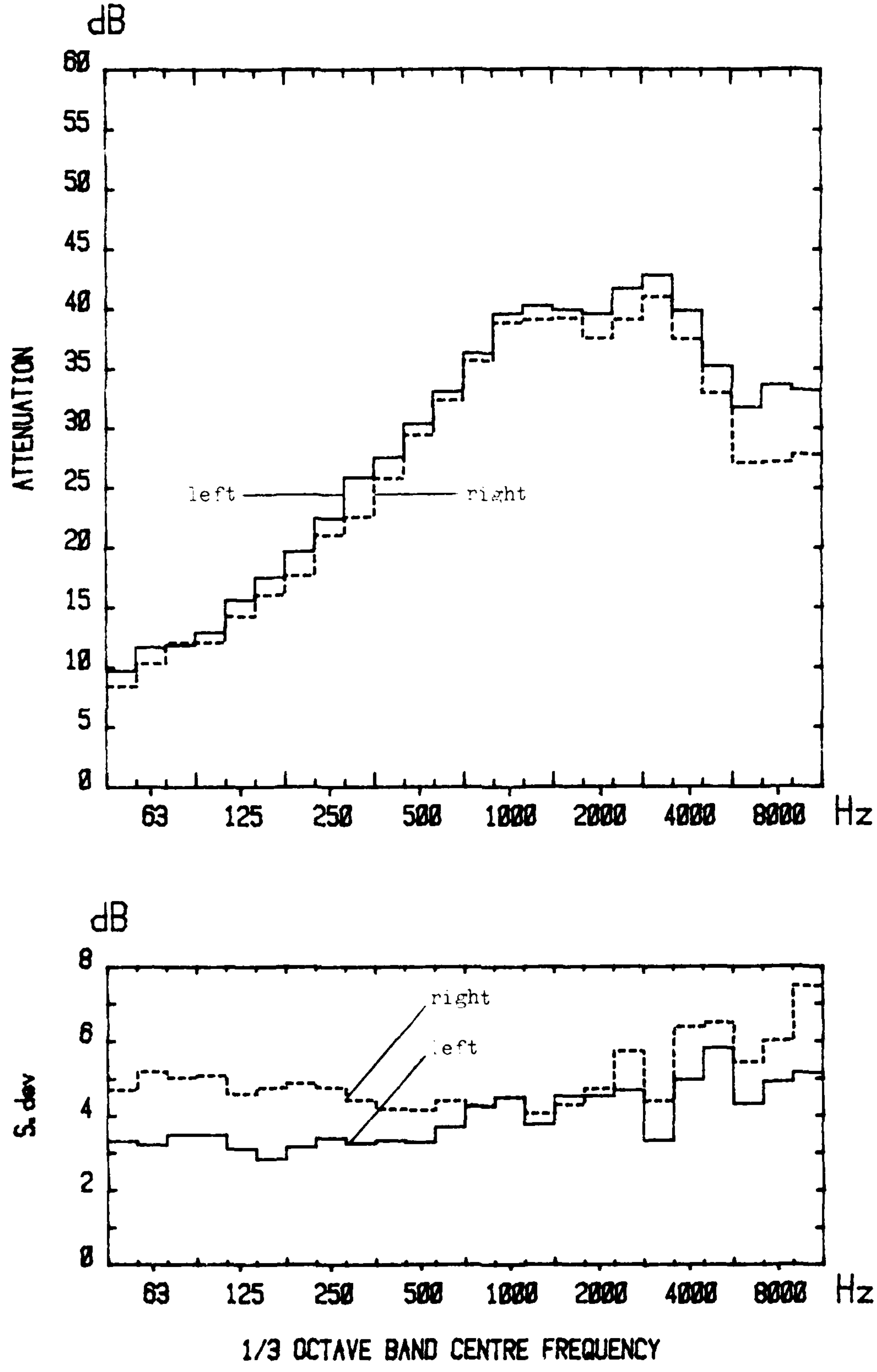

Fig A2 Mean attenuation spectra of earmuffs on experimental headband

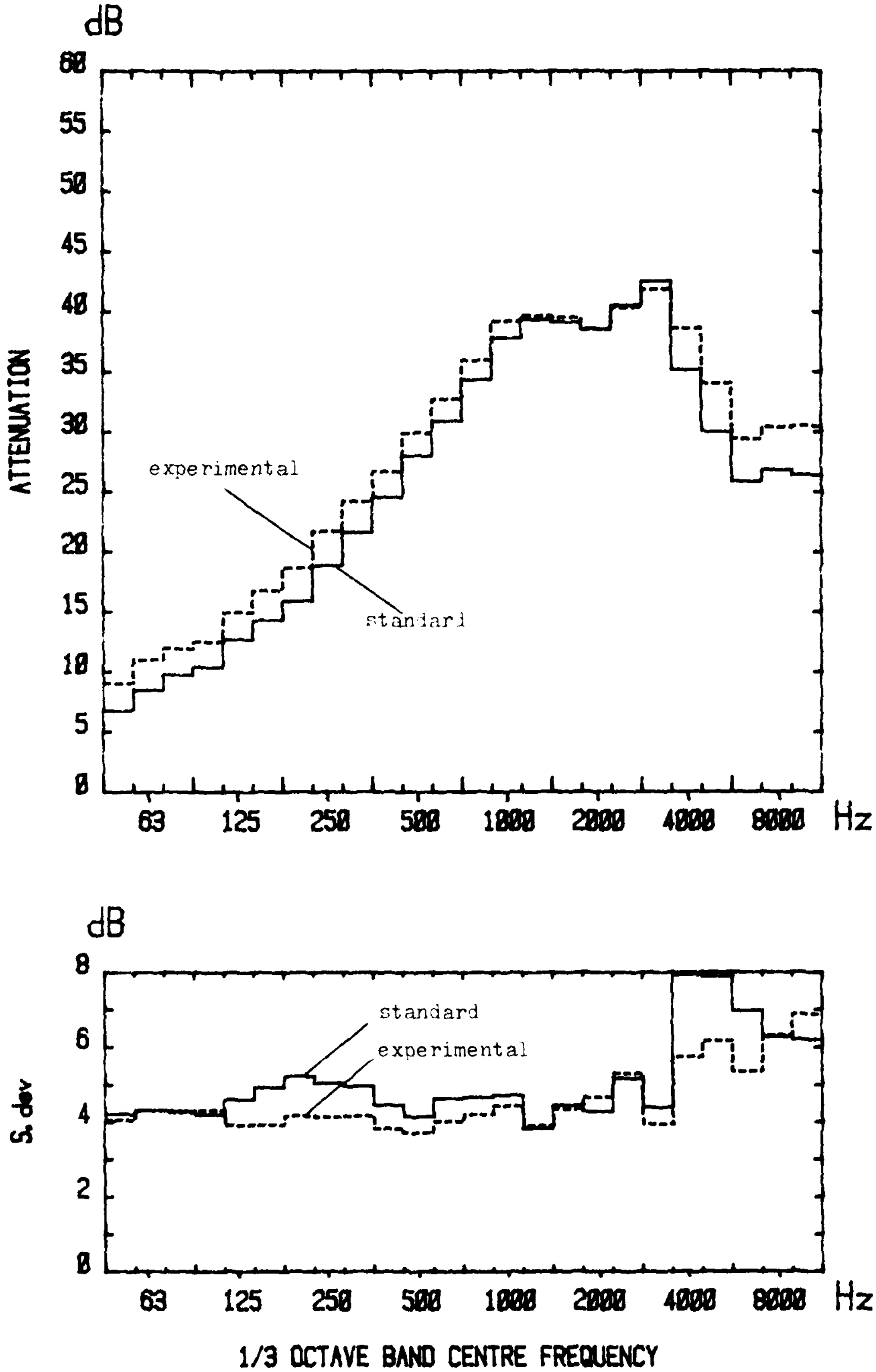

Fig A3 Comparison between the mean attenuation spectra for the two headbands

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REFERENCES

No.	Author	Title, etc
1	G.M. Rood	A comparison of methods for measuring the acoustic attenuation of hearing protectors. RAE Technical Memorandum FS 160 (1978)
2	M.K. Cogger J.A. Chillery	Measurement of the acoustic attenuation of flight helmet earshells. RAE Technical Memorandum FS 352 (1980)
3	British Standards Institution	Estimating the risk of hearing handicap due to noise exposure. BS 5330 (1976)
4	British Standards Institution	British standard method for the measurement of real ear attenuation at threshold of hearing protectors. BS 5108 (1974)
5	G.M. Rood	In-situ measurement of the attenuation of hearing protectors by the use of miniature microphones. Paper presented at the International Symposium on personal hearing protection in industry, 14-16 May 1980, University of Toronto, Canada

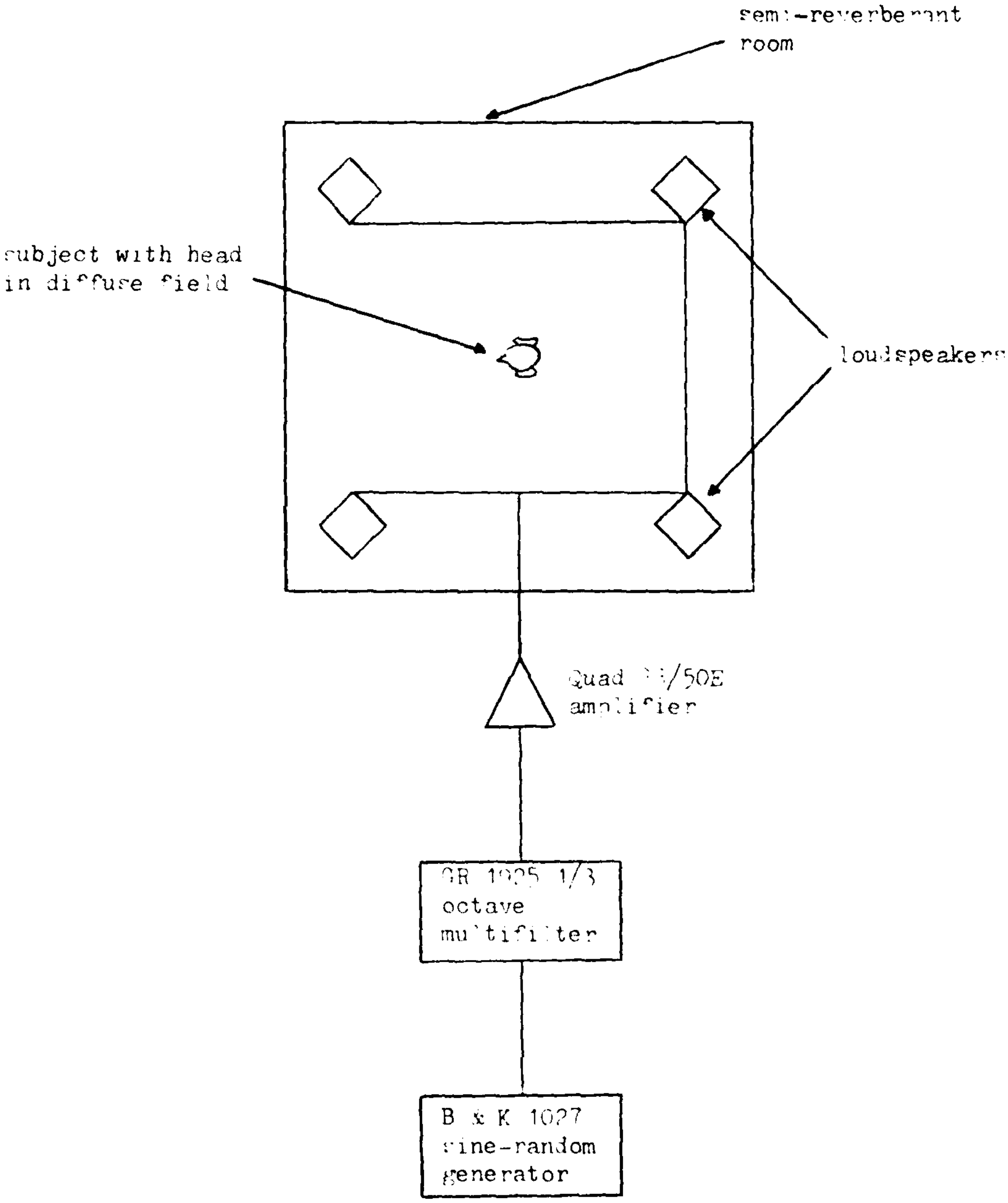

Fig 1 Equipment used to generate noise fields

Fig 2

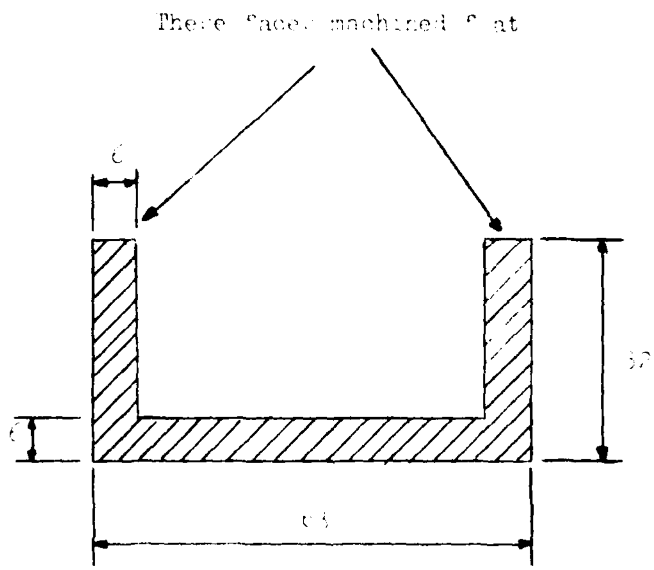

Fig 2 Section of brass cup used to measure the isolation of the Artificial Ear

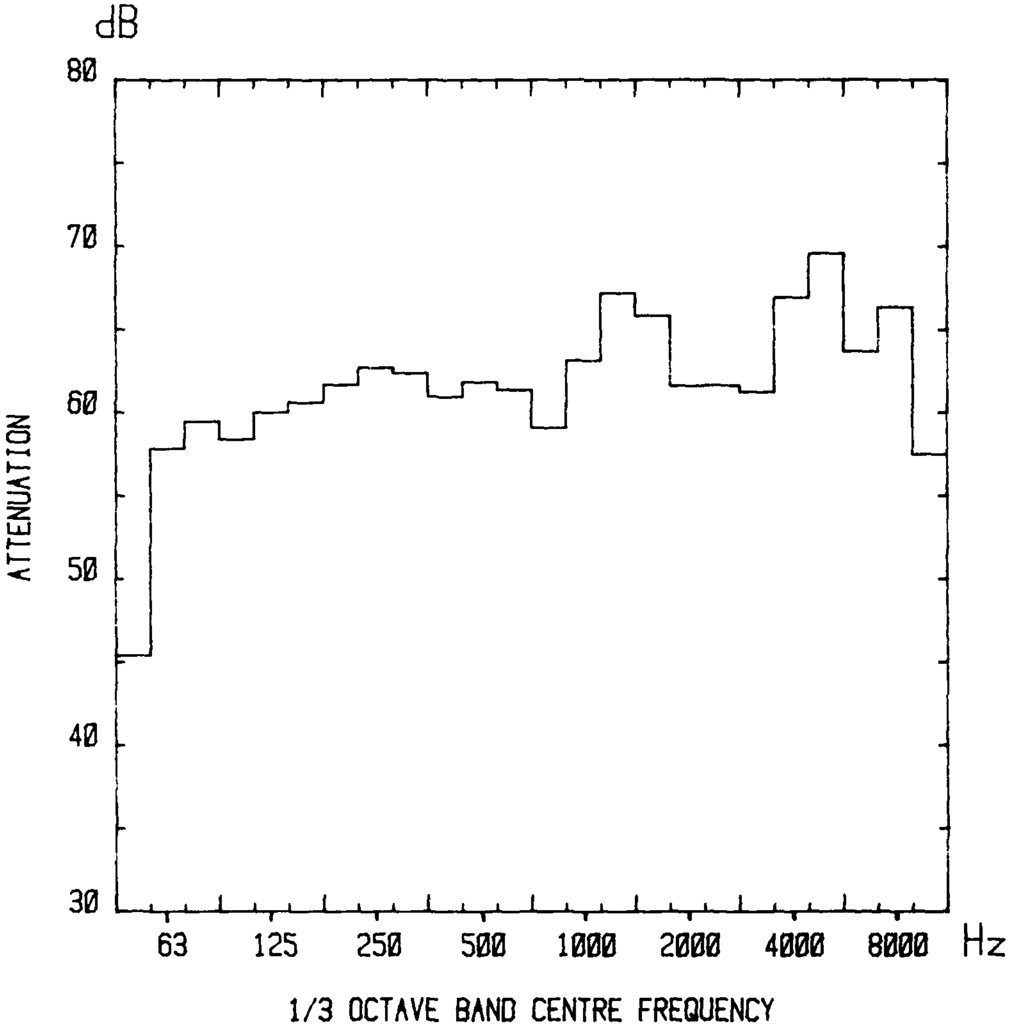

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Fig 3 Isolation of the Artificial Ear

Fig 4

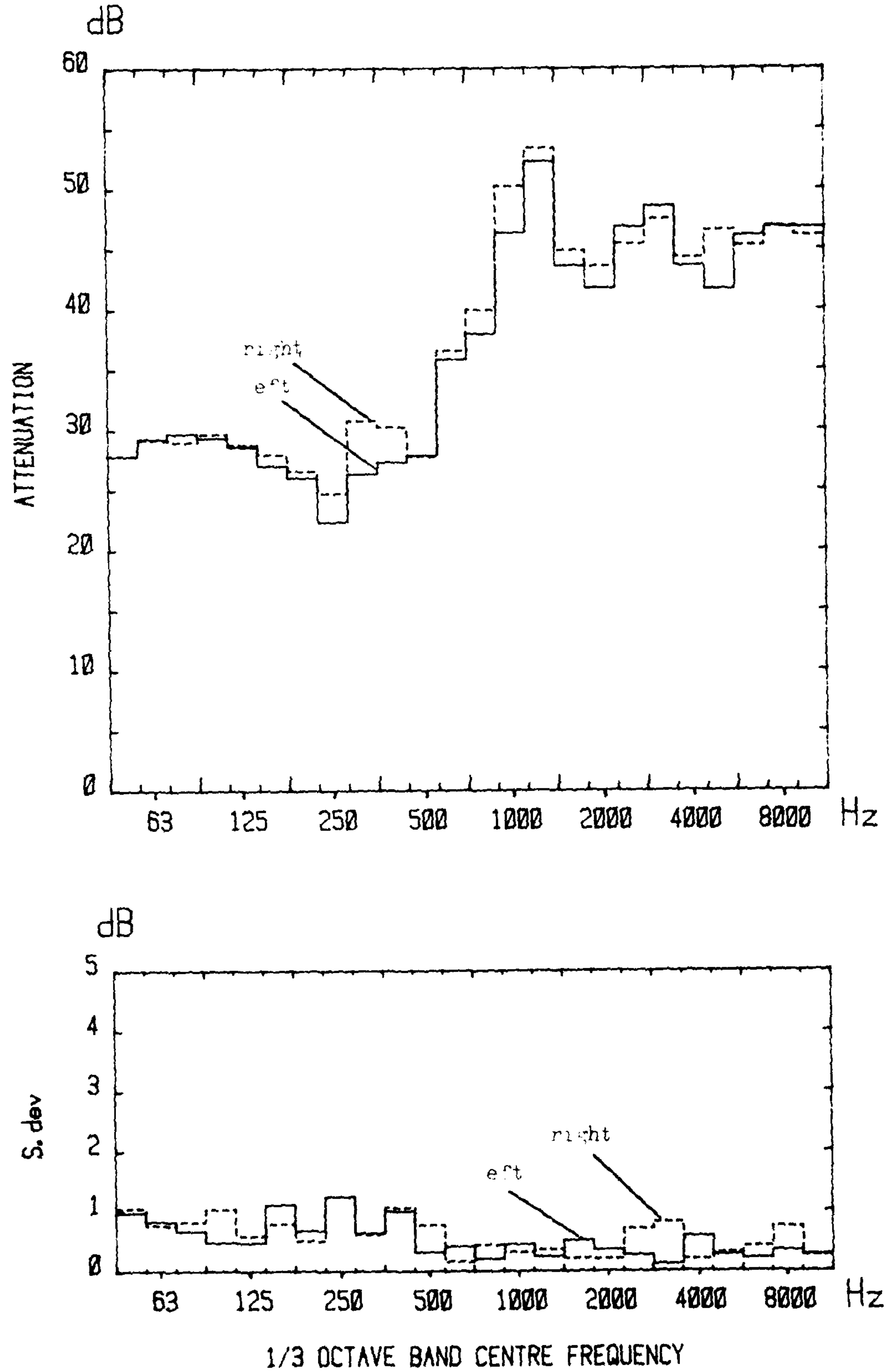

Fig 4 Mean attenuation spectra for earmuffs A, measured by objective methods

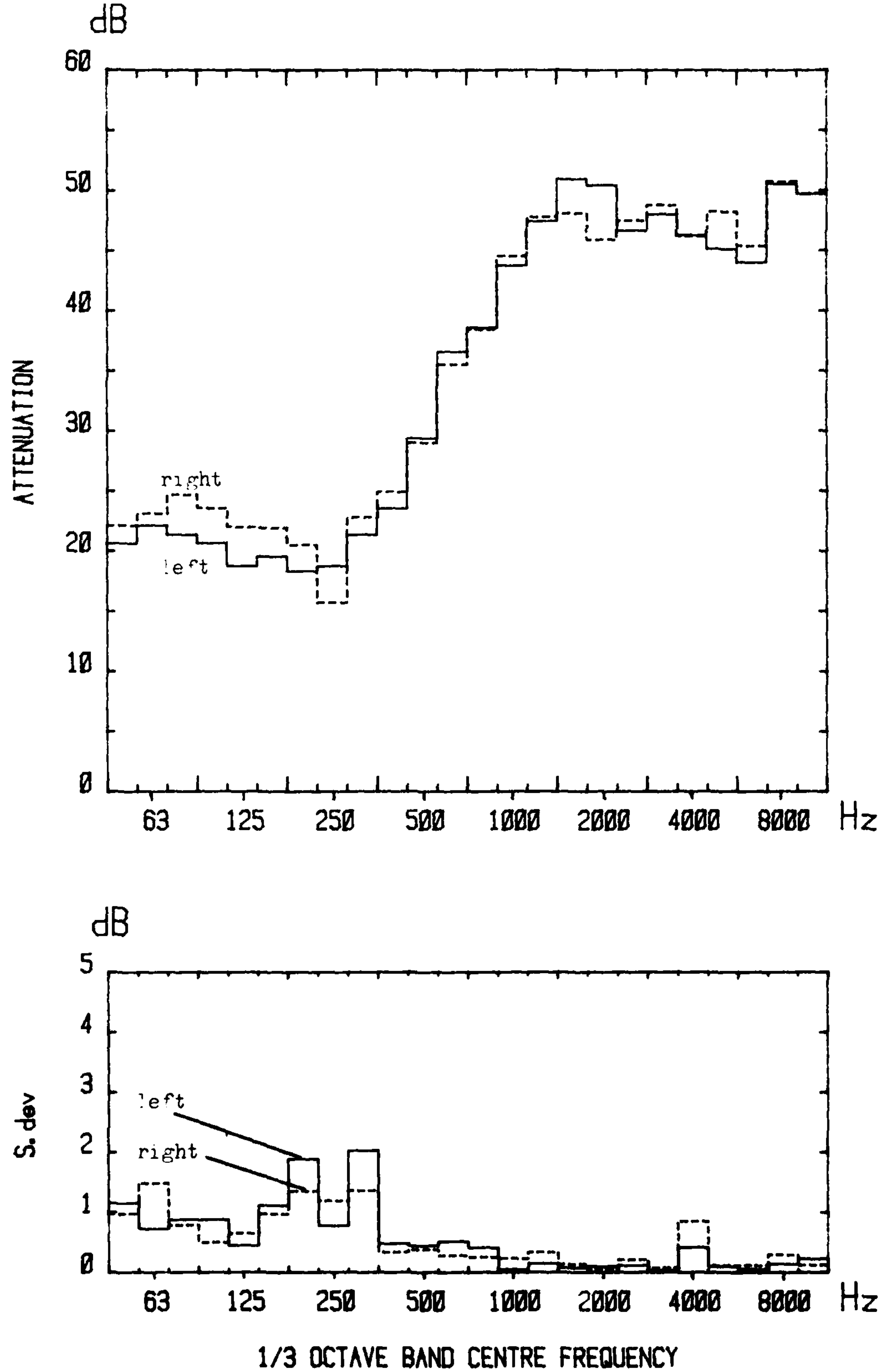

Fig 5 Mean attenuation spectra for earmuffs B, measured by objective methods

Fig 6

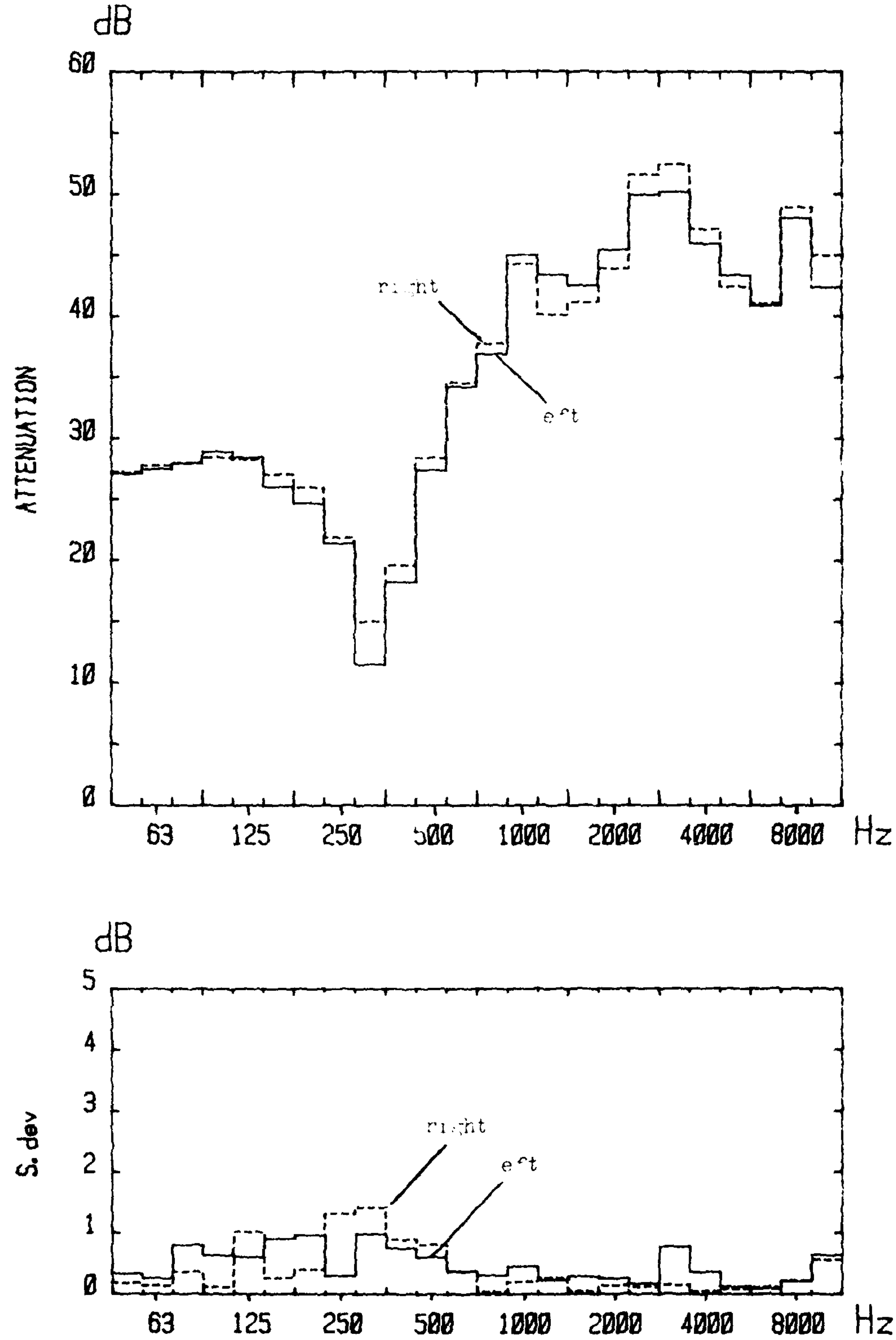

Fig 6 Mean attenuation spectra for earmuffs C, measured by objective methods

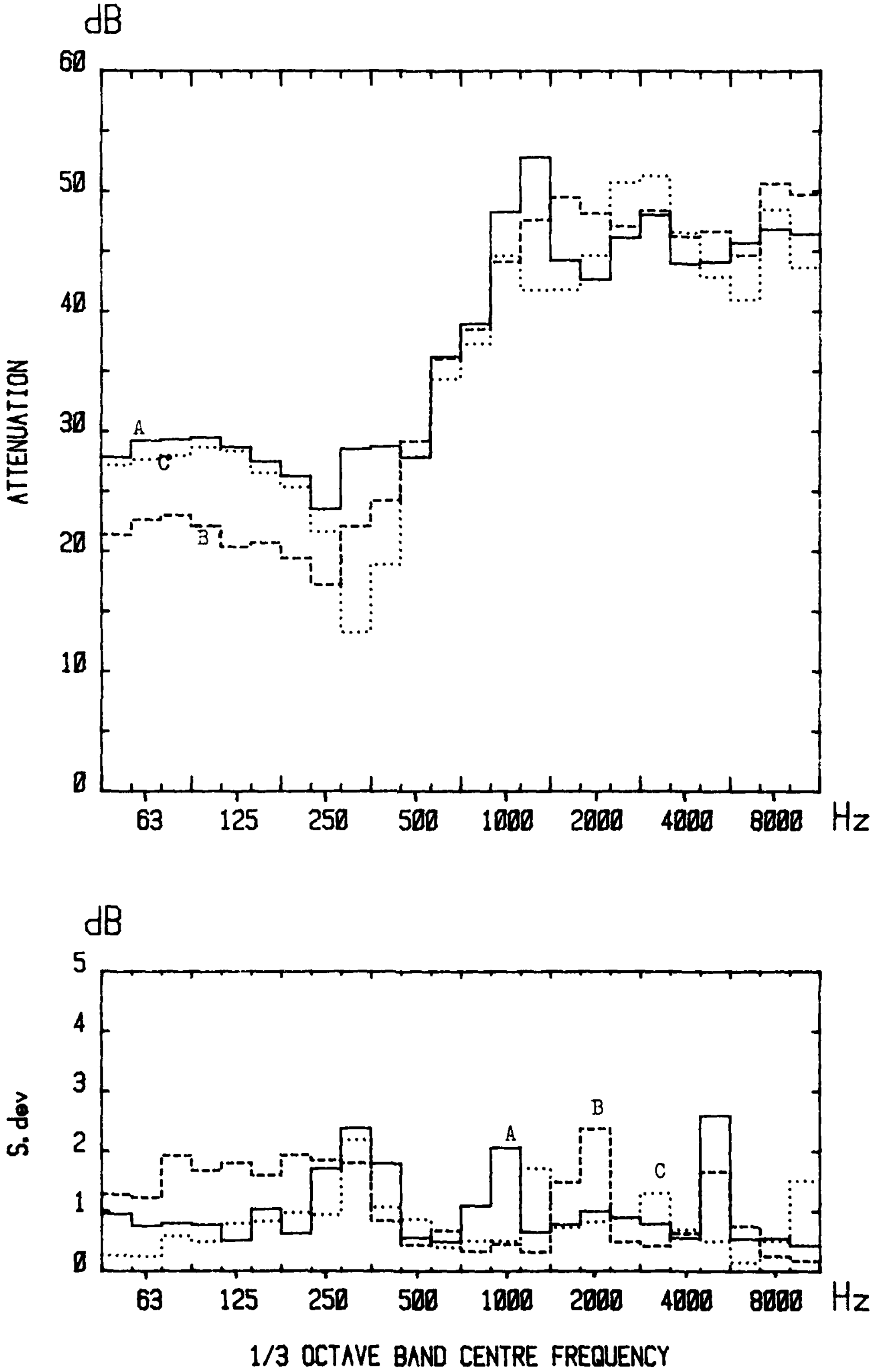

Fig 7 Comparison of mean attenuation spectra for each type of earmuff, measured by objective methods

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Fig 8

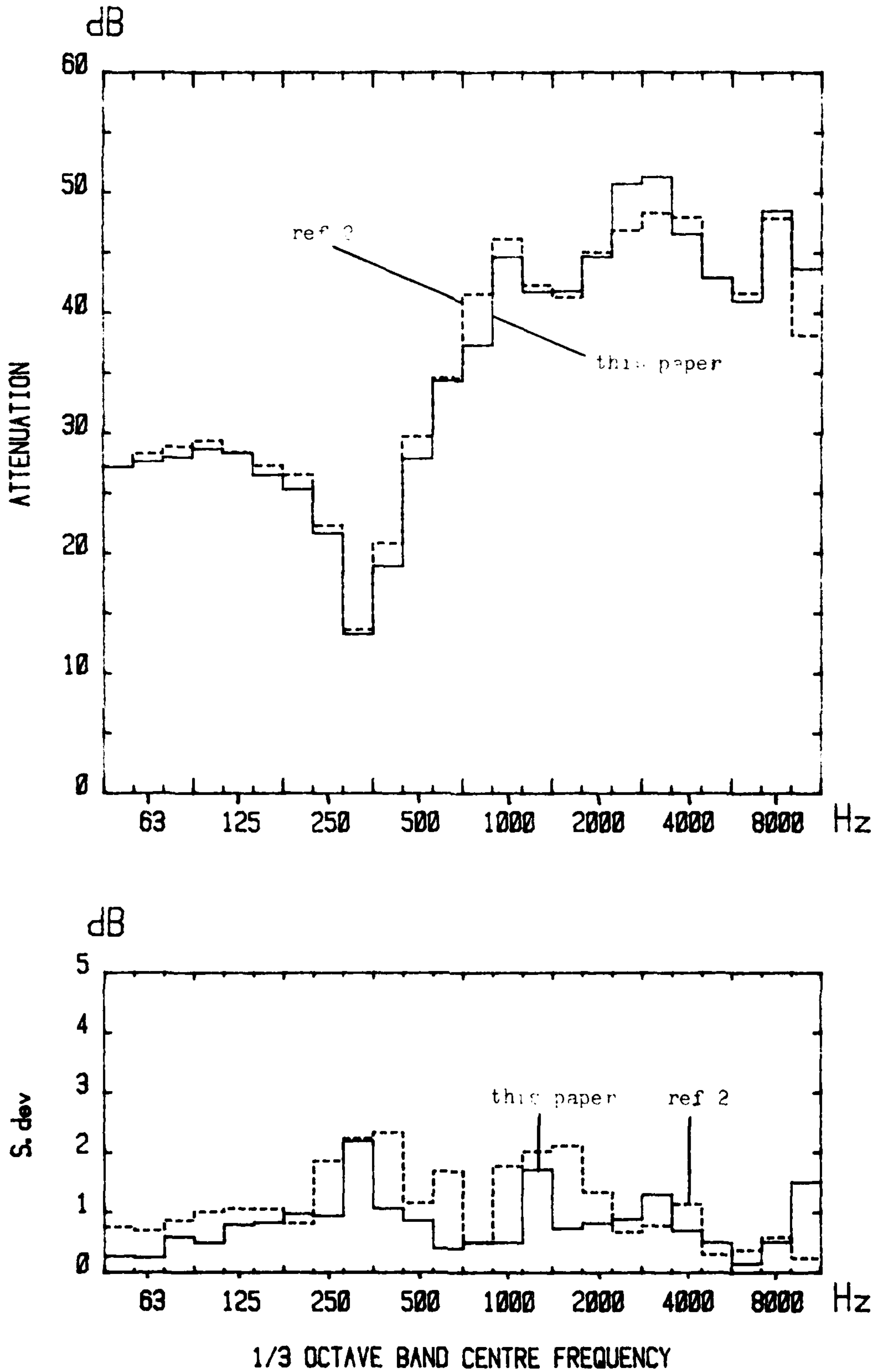

Fig 8 Comparison of mean attenuation spectra for earmuffs C, with Ref 2, measured by objective methods

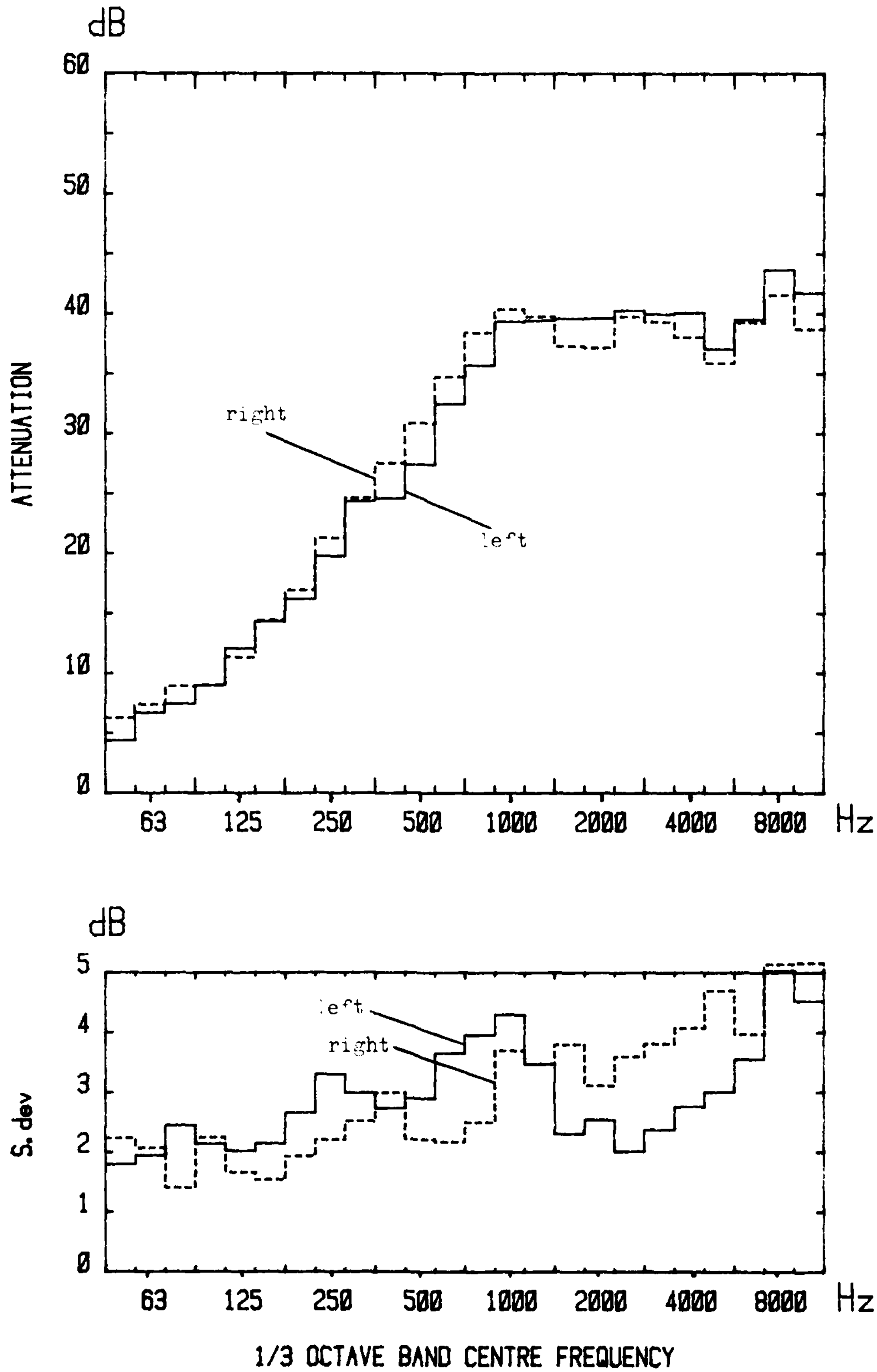

Fig 9 Mean attenuation spectra for earmuffs A, measured by semi-objective methods

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Fig 10

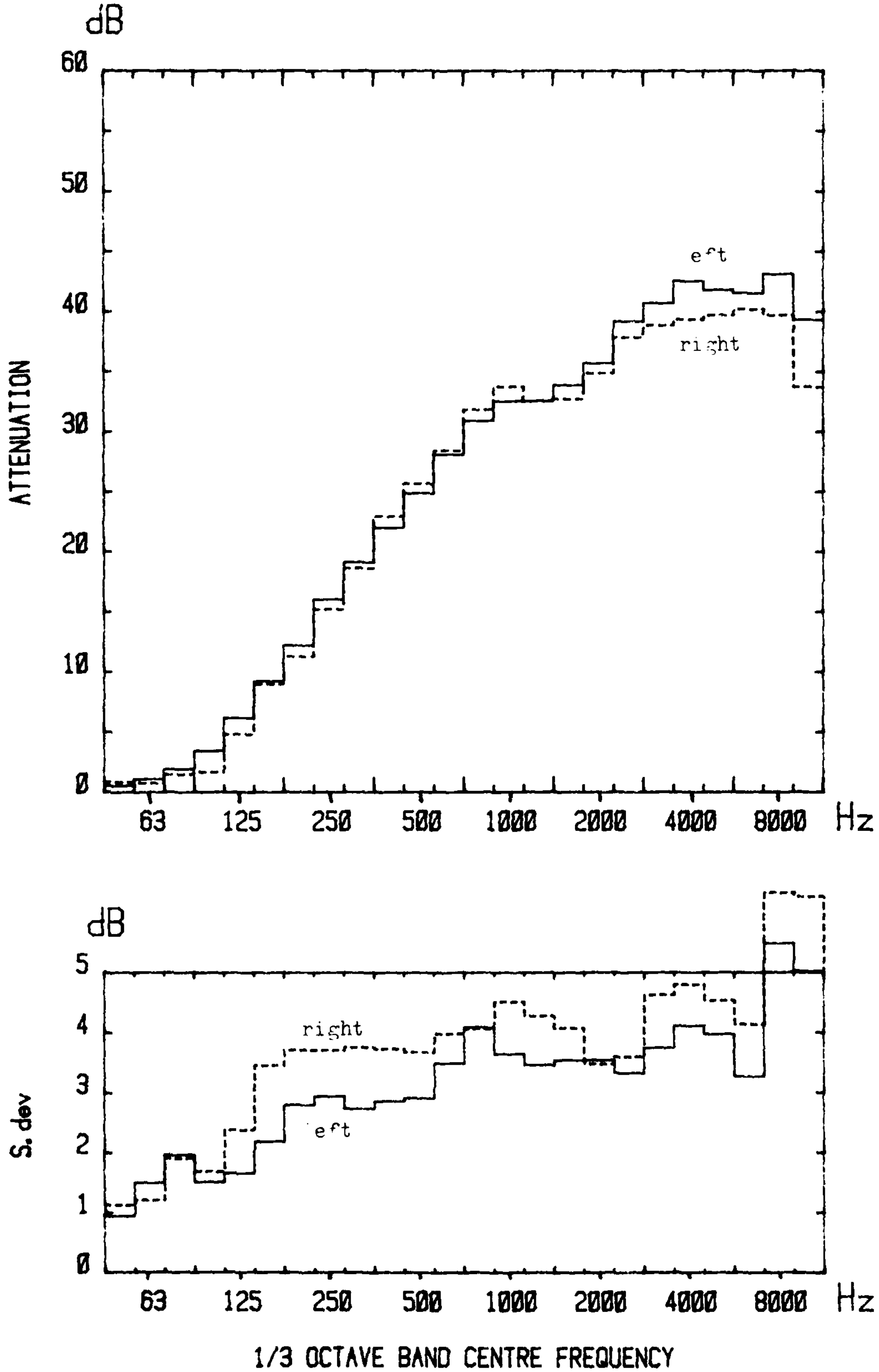


Fig 10 Mean attenuation spectra for earmuffs B, measured by semi-objective methods

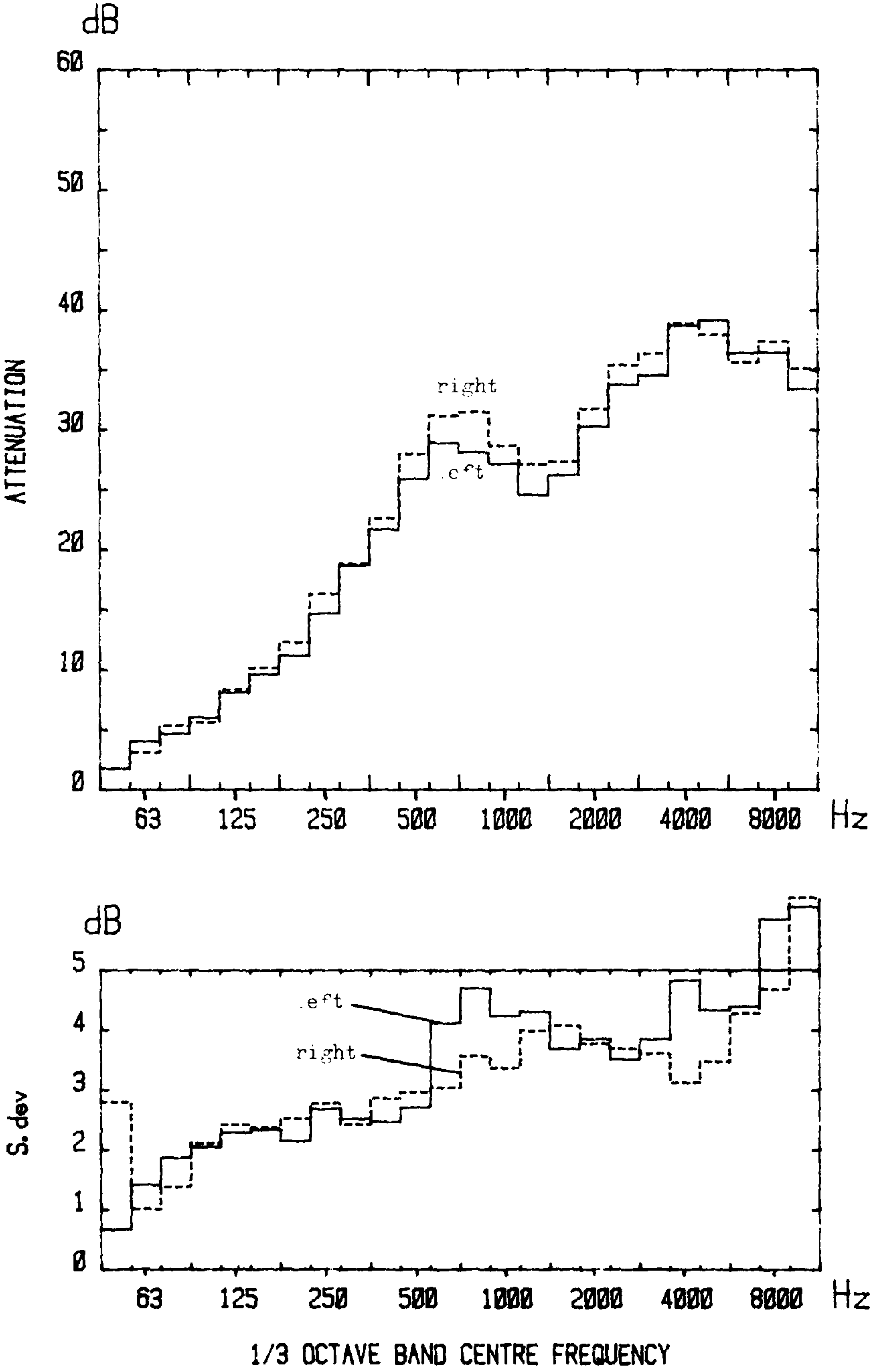
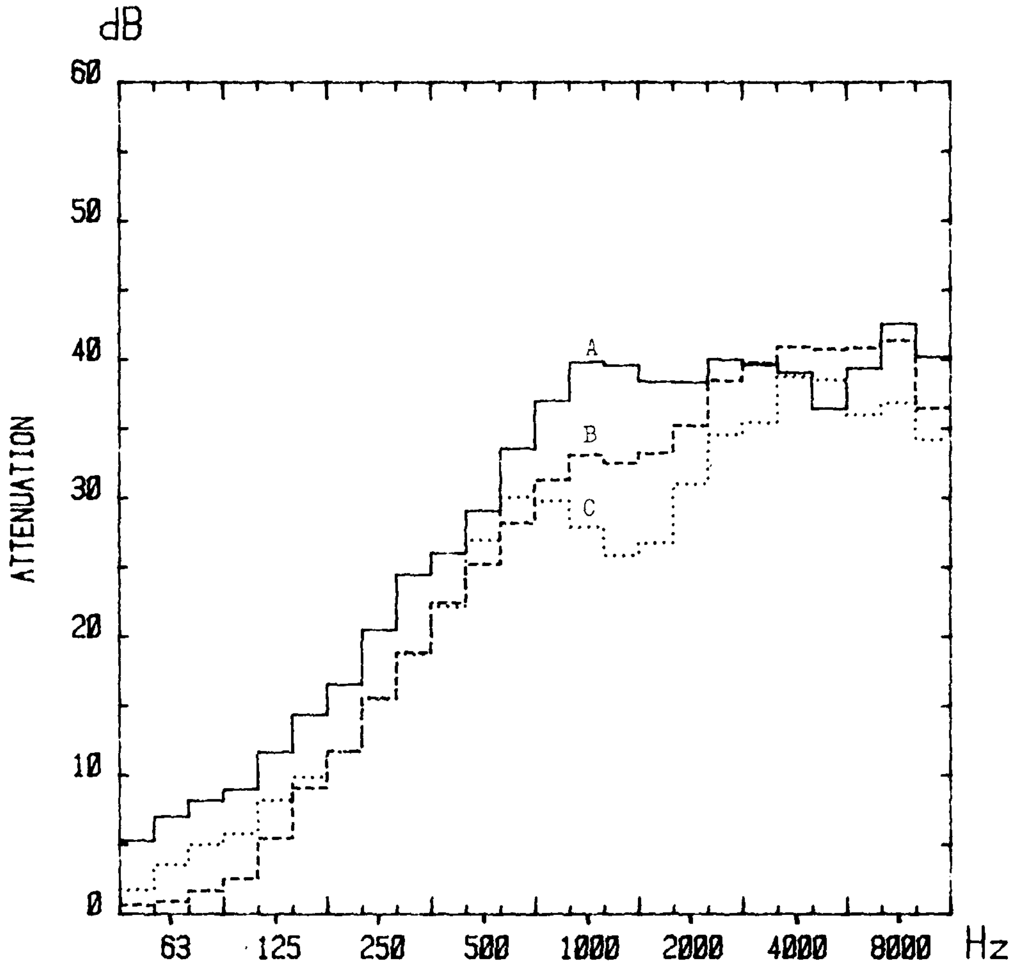


Fig 11 Mean attenuation spectra for earmuffs C, measured by semi-objective methods

Fig 12



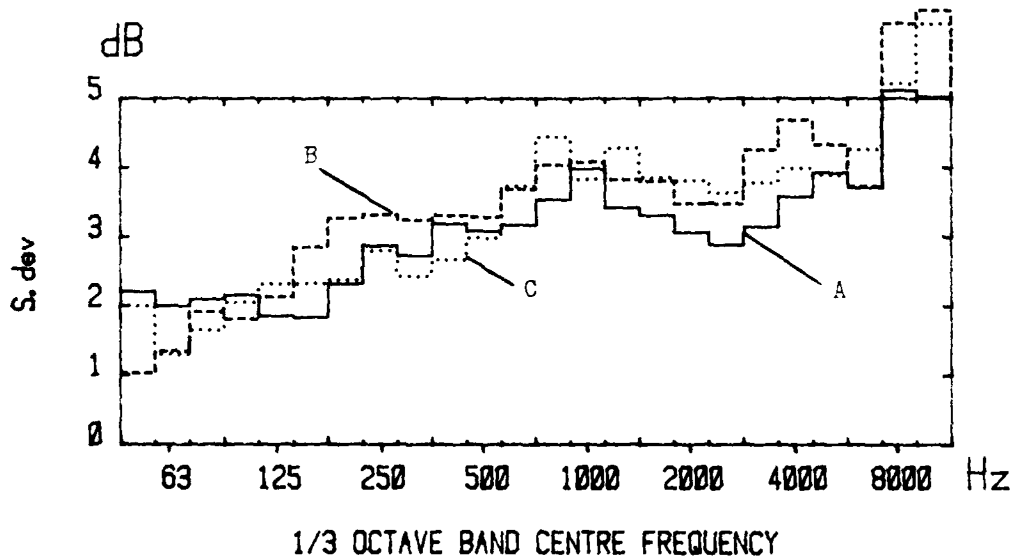


Fig 12 Comparison of mean attenuation spectra for each type of earmuff, measured by semi-objective methods

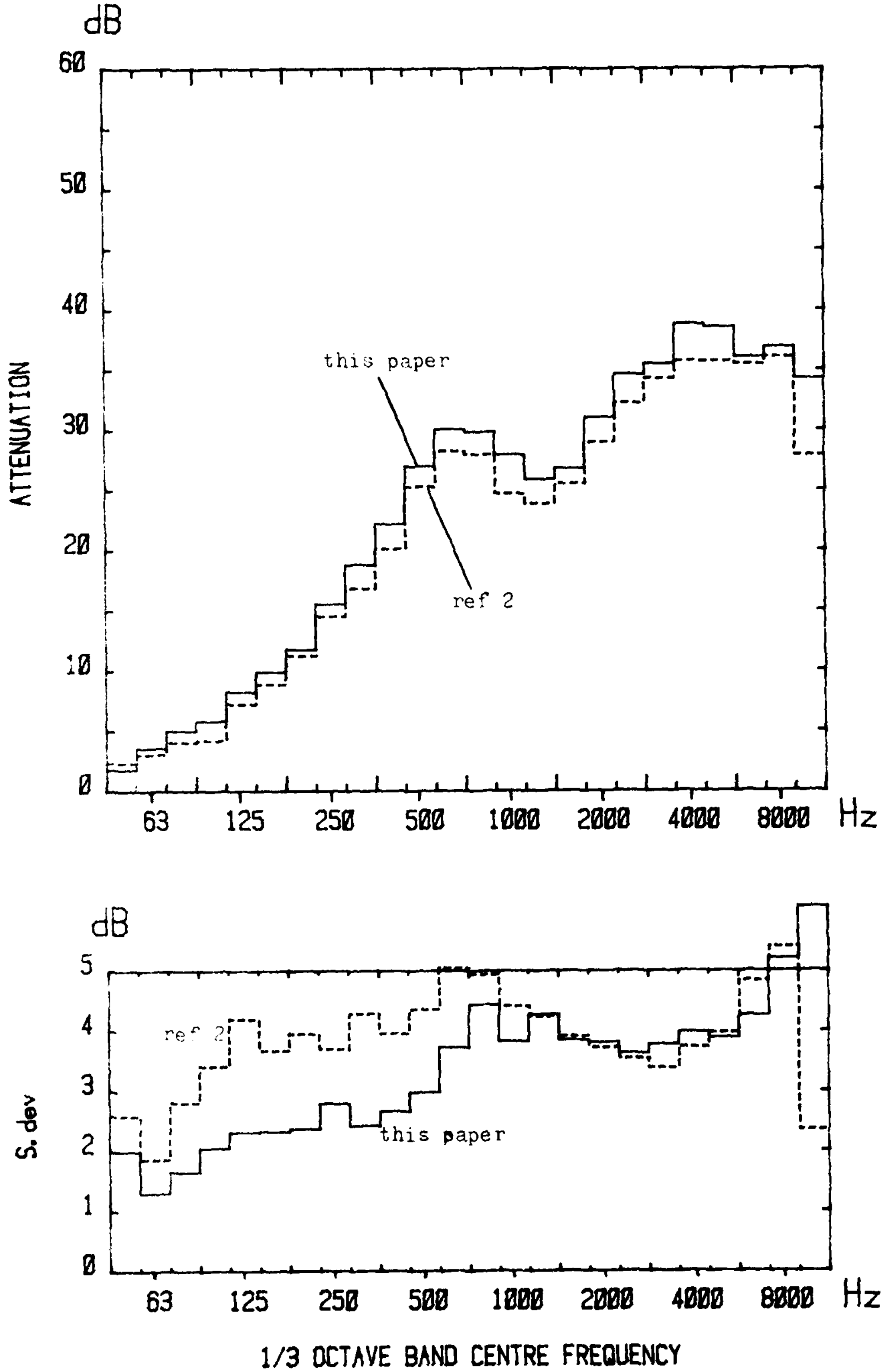


Fig 13 Comparison of mean attenuation spectra for earmuffs C with Ref 2, measured by semi-objective methods

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1. DRIC Reference (to be added by DRIC)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification/Marking
	RAE TM FS 371	N/A	UNCLASSIFIED

5. DRIC Code for Originator	6. Originator (Corporate Author) Name and Location
7673000W	Royal Aircraft Establishment, Farnborough, Hants, UK

5a. Sponsoring Agency's Code	6a. Sponsoring Agency (Contract Authority) Name and Location
N/A	N/A

7. Title Measurement of the attenuation of experimental earmuffs for the Mk 4 flight helmet

7a. (For Translations) Title in Foreign Language

7b. (For Conference Papers) Title, Place and Date of Conference

8. Author 1. Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	Pages	Refs.
Cogger, M.K.	James, S.H.		December 1980	26	5

11. Contract Number	12. Period	13. Project	14. Other Reference Nos.
N/A	N/A		

15. Distribution statement

(a) Controlled by –

(b) Special limitations (if any) –

16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Attenuation. Earmuffs.

17. Abstract

Acoustic attenuation measurements have been made on three pairs of earmuffs including samples of alternatives to the B2 production shells used on the Mk 4 flight helmet, using both the objective and semi-objective methods of test. In addition, an example of the B2 production earmuffs was also tested.

The differences between the results are discussed with reference to the relative merits of the earmuffs and the reliability of the test methods.

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